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January 28, 1994

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FEDERAL COMMUNICATIONS COMMISSION
OFFICE OF SECRETARY

Mr. William Caton
Acting Secretary
Federal Communications Commission
Room 222, stop code 1170
1919 M St., N.W.
Washington, DC 20554

Re: Ex Parte Comments in PR Docket No. 92-235

Dear Mr. Caton:

In accordance with Section 1.1206 of the Commission's Rules, on behalf of United Parcel Service I am enclosing two copies of the Ex Parte Comments in PR Docket No. 92-235 concerning the "refarming" of private land mobile spectrum below 512 MHz. The Ex Parte Comments supplement Appendix 1 to the UPS Reply Comments in the proceeding filed July 30, 1993, and were prepared by Stu Froelich, 220 MHz lead engineer of IIMorrow, Inc., a UPS subsidiary.

Please contact me if there are any questions concerning this matter.

Respectfully,

David E. Hilliard

David E. Hilliard

Enclosure

cc: Mr. Doron Fertig
Room 5202, 2025 M St., N.W., stop code 1700A3

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United Parcel Service Ex Parte Comments
FCC PR Docket 92-235
January 28, 1994

Introduction

Ongoing analysis of published specifications subsequent to the preparation of the Reply Comments of United Parcel Service in Docket 92-235 ("Reply Comments") has provided the basis for an update of one section of the spectrum efficiency comparisons in the Reply Comments. The discussions and quantified results in the Reply Comments are generally unaffected. However, some factors of interest in one result merit revisiting in light of other published material.

UPS remains very interested in furthering the progress of the FCC's private land mobile radio (PLMR) "refarming" efforts. These ex parte comments are submitted to reinforce the material presented in the Reply Comments to contribute to the attainment of the goals of Docket 92-235.

1. Technical Summary

The Reply Comments discussed practical scenarios in which packet data transmission can attain two order of magnitude improvements in spectrum efficiency as compared to typical mobile RF communications. The Reply Comments also provided quantified comparisons of time x bandwidth efficiency and coverage capability for a number of different mobile RF data technology options.

Section 3.5. of Appendix 1 of the Reply Comments compared relative spectrum efficiency for UPS's type accepted 220 MHz mobile radio technology, operating at 4,000 bits per second (4 kbps) in 5 kHz channels, with an emerging mobile RF data system transmitting at 19.2 kbps with nominally 30 kHz channelization.

These ex parte comments focus on two basic technical points:

(1) Details of the 19.2 kbps system are discussed much more explicitly in its more recent public specification[1] than in the preceding version.[2] Based on details in the more recent document, the system's multiple access protocol can attain higher efficiency than previously estimated.

(2) Based on adjacent channel protection ratios specified in the more recent document on the 19.2 kbps system,[3] operating the system without adjacent channel coordination in PLMR bands would require channel width greater than 30 kHz.

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[1] "Cellular Digital Packet Data System Specification," Release 1.0, July 19, 1993.

[2] "Cellular Digital Packet Data System Specification," Preliminary Release V. 0.8, March 19, 1993.

[3] CDPD Release 1.0, *op. cit.*, p. 408-7.

Protocol efficiency higher than the previously estimated values increases the relative spectrum efficiency calculated for the 19.2 kbps system. However, accounting for the fact that the 19.2 kbps system effectively requires more than 30 kHz channel width decreases its calculated relative spectrum efficiency.

Tables 1 and 2 in these ex parte comments summarize the spectrum efficiency impacts of these factors. Tables 1 and 2 are updated versions of Tables 2a and 2b from Appendix 1 of the Reply Comments.

On balance, the 4 kbps/5 kHz technology maintains a significant spectrum efficiency advantage compared to the 19.2 kbps wider bandwidth system. The result is not greatly changed, but updating the factors leading to the result is important in illustrating the comparison method.

The 19.2 kbps system uses a Digital Sense Multiple Access with Collision Detection (DSMA/CD) protocol, similar to Carrier Sense Multiple Access with Collision Detection (CSMA/CD), to manage mobile radio transmission traffic in each channel.[4] Similar protocols with various acronyms have evolved over the last two decades, e.g. busy tone multiple access (BTMA).[5] DSMA and DSMA/CD protocols are sometimes referred to as "busy bit."

In addition to the two basic technical points, the following comments also discuss how the use of "busy bit" protocols tends to place limitations on coverage options in PLMR bands.

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[4]*Ibid.*, p. 402-4.

[5]Kleinrock, L., and Tobagi, F. "Packet Switching in Radio Channels," IEEE *Transactions on Communications*, Vol. COM-23, No. 12, December, 1975, pp. 1400-1433.

Table 1. Comparison of RF Time x Bandwidth Efficiency UPS 4 kbps/5 kHz Hybrid Multiple Access System and 19.2 kbps DSMA/CD System

Message Type	Size (bytes)	Average RF Air Time Per Message (sec.)		Time x Bandwidth	
		4 kbps	19.2 kbps	4 kbps	19.2 kbps
Full Terminal Screen*	2048	8.9	1.4	44500	67200
Long Haul Arrival	250	1.2	.2	6000	9600
Package Track	100	.54	.1	2700	4800
Hub Shifter	20	.17	.05	850	2400
Vehicle Track**	4	.025	.05	125	2400

*This is not planned as a common UPS mobile data application, but is included to compare performance with a relatively long message.

**This is a specially compressed vehicle tracking message, using polling instead of random access in the 4 kbps/5 kHz system. The other applications shown here use random access in both systems.

Table 2. Relative Spectrum Efficiency Based on Time x Bandwidth for Data Messages UPS 4 kbps/5 kHz Hybrid Multiple Access System and 19.2 kbps DSMA/CD System

Message Type	Relative Spectrum Efficiency	
	4 kbps	19.2 kbps
Full Terminal Screen	100%	66%
Long Haul Arrival	100%	63%
Package Track	100%	56%
Hub Shifter	100%	35%
Vehicle Track	100%	5%
Relative Average	100%	45%

2. DSMA/CD Efficiency

As mentioned in the Reply Comments, a practical formula for maximum CSMA/CD protocol efficiency is:

$$\text{efficiency} = \frac{1}{1 + 6.44 \text{ x a}} \text{ x } 100\%$$

where the critical parameter "a" is the system end-to-end propagation delay divided by the transmission length.[6]

In other words, "a" is the time from the beginning (or end) of a transmission until the busy (or idle) state of the channel is known to the rest of the stations on the channel, divided by the transmit burst duration. In a well designed DSMA or DSMA/CD implementation, the effective equivalent to "a" is the interval between busy/idle sense flags in the base station transmission stream, divided by the average mobile transmit burst duration. In some systems, the busy/idle flag is a single bit, hence the common term "busy bit."[7]

Based on the more recent public specification, the time required for a minimum length mobile transmission burst in the 19.2 kbps system would effectively be about 28 ms, due to the following factors: propagation delay, including delay through radio circuitry; the bit sequence transmitted during mobile transmit power rampup; bit synchronization preamble; forward error correction (FEC) block duration; a portion of the bit sequence transmitted during mobile transmit power rampdown; and the effective quantization of inbound link (i.e. reverse link, mobile to base) time due to the interval between busy/idle sense flags.[8]

Due to the mechanisms for detecting collisions and stopping conflicting mobile transmissions,[9] the "CD" aspect of the 19.2 kbps system's RF channel protocol does not take full effect until about 53 ms into the burst time.

Assessing average RF air time to allow for various message lengths for the 19.2 kbps system involves: number of data and address bits in the message; message framing; propagation delay; rampup/down bits; bit synchronization preamble; FEC blocks; time between sense flags;

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[6]Schwartz, M. *Telecommunication Networks*. Reading, Addison-Wesley, 1987, pp. 442, 445.

[7]CDPD Release 1.0, *op. cit.*, p. 402-34, refers to the time between busy/idle flags as the "collision interval." Schwartz, *op. cit.*, p. 444, uses the term "collision interval" with a somewhat different meaning. However, using the critical parameter "a" as discussed in the preceding paragraphs provides a valid expression for the upper bound efficiency attainable with the 19.2 kbps DSMA/CD protocol.

[8]CDPD Release 1.0, *op. cit.*, pp. 402-22 - 402-30.

[9]*Ibid.*, p. 402-30.

automatic repeat requests (ARQ); and protocol efficiency.

The Schwartz formula given at the beginning of this section is used to evaluate attainable protocol efficiency for the 19.2 kbps system for Tables 1 and 2, even though for short packets, the minimum burst duration and the time required to stop collisions reduce maximum efficiency of the 19.2 kbps system to 5-10% less than the result given by the Schwartz formula. However, as discussed in preceding paragraphs, the most important factor in determining attainable efficiency with the 19.2 kbps DSMA/CD system is the busy/idle flag interval, normalized to the mobile transmission burst length. The busy/idle flag interval, i.e. 60 bit times,[10] about 3 ms at 19.2 kbps, is used to determine the value of "a" for use with the Schwartz formula for various mobile transmission burst lengths.

The 19.2 kbps system assessment in Tables 1 and 2 is based on the more recent public specification.[11] The UPS 4 kbps/5 kHz system assessment is based on analysis, simulations, and system tests. Evaluation focuses on mobile transmitted messages, since mobile transmissions pose the greatest overall challenge to multiple access data system operation.

Tables 1 and 2 compare the 4 kbps/5 kHz and 19.2 kbps wider band technologies at 95% FEC block success rates. Coverage considerations at 95% block success are similar for the two technologies, and are not included in the overall spectrum efficiency comparison. At lower block success rates, ARQ becomes more important. The 19.2 kbps system's DSMA/CD protocol requires the mobile to contend again for channel access when it sends an uncorrectable FEC block.[12] The protocol in the 4 kbps/5 kHz technology uses smaller increments of data and uncontended channel access for mobile ARQ transmissions. This provides significant advantages for the 4 kbps/5 kHz system in more difficult coverage conditions.

3. Adjacent Channel Interference and Bandwidth Usage

The ability to use adjacent channels without coordination is very important for overall spectrum efficiency in refarmed PLMR bands.

The 19.2 kbps system uses GMSK modulation with a transmitter baseband filter time bandwidth product BT = 0.5.[13] The ACI protection ratio at 95% block success for the 19.2 kbps system is 16 dB with 30 kHz channel separation.[14] The 4 kbps technology uses multilevel digital FM

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[10]*Ibid.*, p. 402-30.

[11]*Ibid.*

[12]*Ibid.*, p. 402-36.

[13]*Ibid.*, p. 408-32.

[14]*Ibid.*, p. 408-7.

and attains a 48 dB ACI protection ratio at 95% block success with 5 kHz separation.[15]

The practical impact of these ACI performance figures is that the 4 kbps technology can be used on adjacent channels with 5 kHz separation without adjacent channel coordination. Using the 19.2 kbps system in PLMR bands would require adjacent channel coordination or channel separation greater than 30 kHz.

Channel separation for the 19.2 kbps system is in multiples of 30 kHz. Specified protection ratios are for 30 kHz and 60 kHz separation. Protection is excellent at 60 kHz separation.[16]

However, based on published spectrum occupancy for GMSK with various pulse shaping values,[17] with good receiver design uncoordinated adjacent channel use with the 19.2 kbps system's modulation parameters should require only about 48 kHz channel spacing. Hence, for comparison with the 4 kbps/5 kHz technology, 48 kHz bandwidth is used in determining the time x bandwidth product of spectrum resources used by the 19.2 kbps system in Tables 1 and 2.

As mentioned in the Reply Comments, a small time x bandwidth product for the minimum useful transmission duration indicates a mobile data system's capability to optimize spectrum efficiency by using controlled increments of spectrum resources. For the UPS 220 MHz system, with transmission bursts as short as 24 ms duration in a 5 kHz channel,[18] the minimum time x bandwidth increment is 120. For the 19.2 kbps technology, with a 28 ms minimum burst time as discussed herein in section 2, and 48 kHz effective bandwidth usage, the minimum time x bandwidth increment is 1,344, more than ten times the figure for the 4 kbps/5 kHz system.

4. CSMA-Like Protocols Affect Coverage Options in PLMR

Minimizing the parameter "a" (discussed herein, section 2) to optimize throughput in digital protocols based on CSMA, e.g. DSMA and DSMA/CD, requires minimum communication delay between base station receivers which sense mobile transmissions and base station transmitters which signal channel status to other mobiles. This tends to require collocated base station transmitters and receivers.

Requiring collocation limits system deployment options in PLMR bands, where frequencies are typically licensed on a site-by-site basis for independent users. Desirable transmit sites often

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[15]"Reply Comments of United Parcel Service," FCC Docket 92-235, July 30, 1993, Appendix 1, p. 10.

[16]CDPD Release 1.0, *op. cit.*, p. 408-7.

[17]Murota, K. "GMSK Modulation for Digital Mobile Radio Telephony," IEEE *Transactions on Communications*, Vol. COM-29, No. 7, July 1981, pp. 1044-1050.

[18]Froelich, S. "Spectrum Efficient Digital Communications for 220-222 MHz Narrowband Land Mobile Channels," *Proceedings*, IEEE Vehicular Technology Conference, 1993, pp. 322-325, attached to the UPS Reply Comments as Appendix 2.

have high noise backgrounds. The ability to use base station receivers at different sites than the corresponding transmitters can be a valuable option in attaining quality coverage with available sites and licenses for PLMR systems.

The modulation and multiple access used by the 19.2 kbps DSMA/CD system are similar to methods used in PLMR and SMR in recent years. However, the 19.2 kbps DSMA/CD system is designed for cellular bands, in which deployment planning is not constrained by individual site licensing. Requiring collocated base station transmitters and receivers does not pose the issue for cellular that it does for PLMR. The tradeoff is that cellular requires control of hundreds of channels by single entities, which runs contrary to the purpose of the PLMR bands.

In summary, throughput optimization of DSMA, DSMA/CD, or similar "busy bit" protocols can limit coverage design options in PLMR bands. Other protocols can attain rapid random access and high throughput for mobile packet data systems without constraining coverage design options. The UPS 220 MHz technology, for example, uses a hybrid protocol combining desirable features of random and directed access.[19]

Conclusion

Useful spectrum efficiency comparisons can be made between the UPS 4 kbps/5 kHz 220 MHz technology and an emerging 19.2 kbps DSMA/CD data system for wider bandwidth channels. Based on pragmatic experience with PLMR and SMR systems, the basic features of the 19.2 kbps system are comparable with the general state of the art of land mobile RF data technologies currently available for channels from 12.5 kHz to 30 kHz.

The updated comparisons presented in these ex parte comments illustrate the same basic result as stated in the UPS Reply Comments in Docket 92-235: wideband operation is not a requirement for mobile data system spectrum efficiency. Ongoing UPS development work, e.g. enhanced FEC methods and use of multiple RF bit rates while maintaining rigorous spectrum control and efficient multiple access, can make the comparisons even more favorable to the narrowband technology.

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[19]*Ibid.*